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ABSTRACT

Outdoor leaders constantly face problems created by water shortage and, to act effectively, must thoroughly understand the body's use of water and the ways to delay dehydration when water shortage occurs. Dehydration begins when there is a negative water balance, or more water lost than ingested, and progresses from the stage of dryness, to the "cotton mouth" stage, and finally to the stage of structural degeneration. The symptoms of dehydration progress from thirst and general uneasiness to sensory impairment and inability to think rationally. Dehydration can be counteracted by increasing water intake and reducing water loss. The body assimilates fresh water most easily, but other water sources are available to the knowledgeable person. For example, urine of a fully hydrated person may be ingested while urine of a dehydrated person should not be ingested, though it can be used to lower skin temperature through evaporation; wash wounds, stings, and bites; or operate a solar still. Reduction of water loss is accomplished by proper ingestion of available water, preventing perspiration, using clothing to protect from heat and evaporation, and avoiding all types of dehydrators, i.e., alcohol, blood, salt, proteins, and fats. (JH)

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Water - Problems and Solutions

A Report Concerning the Problems and Solutions of Negative Water Balance

by

Alan Ewert

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Charts and Illustrations

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As Outdoor Leaders we are constantly faced with the problems created by dehydration and water shortage. Besides fulfilling the responsiblilty of informing our students of the effects of water shortage, we are faced with the actual consequences of lack of water.

The purpose of this report is to expose many of the old wives tales concerning water usage, as well as to explore many of the actual usages and problems of water or lack of it. The main source of information was Thirst-Physiology of the Urge to Drink and Problems of Water Lack, by A. V. Wolf, 1958, and The Physiology of Human Survival, edited by Dr. O.G..Edholm and A.L. Bacharach, 1965.

Before the problems of water shortage are discussed, the question of what water does for the body must be answered. The human embryo consists of over ninety five percent water. The percentage drops to seventy to seventy-three percent with age as the maturing tissues become more rigid and of a higher tensile strength. Water is a mandatory factor in food metabolism, muscle tonicity, waste elimination, cellular upkeep, and temperature regulation.

As an Outdoor Leader the all-encompassing factor is water balance. Water balance is simply a ratio of the amount of water ingested to the amount of water lost. This water loss occurs through evaporation, waste elimination, respiration, and tissue destruction (such as burns). Water gain is accomplished primarily through water ingestation and food oxidation. This water loss and gain is illustrated in Chart 1 on the following page.

Thirst is often thought to be indicative of body needs. Such is

frequently not the case. This is because there are two types of thirst; local and general. Local thirst, often referred to as "false thirst", has symptoms which are centered around the esophagus and throat. It occurs primarily through the drying of the cells in the throat area. With the application of water, these cells tend to rehydrate and the thirst symptoms are alleviated with the possibility of the total body needs not being satisfied. These local thirst symptoms are also alleviated through the use of a "regulation pebble", such as a small stone, button, twigs, gum, hard candy, or an antidipticum (remedies that lessen thirst such as camphor, ether, peeled root of licorice, and opium).[1] It should be noted that these antipticums may excite saliva flow but otherwise the effects are largely psychological.[2]

Chart 1.

Water Gain	ml.
Liquid Food	1100
Solid Food	500-1000
Water of Oxidation	300-400
Total	1900-2500
Water Losses	**ml.**
Urine	1000-1400
Insensible Perspiration	500
Respiration	300-500
Feces	100
Total	1900-2500

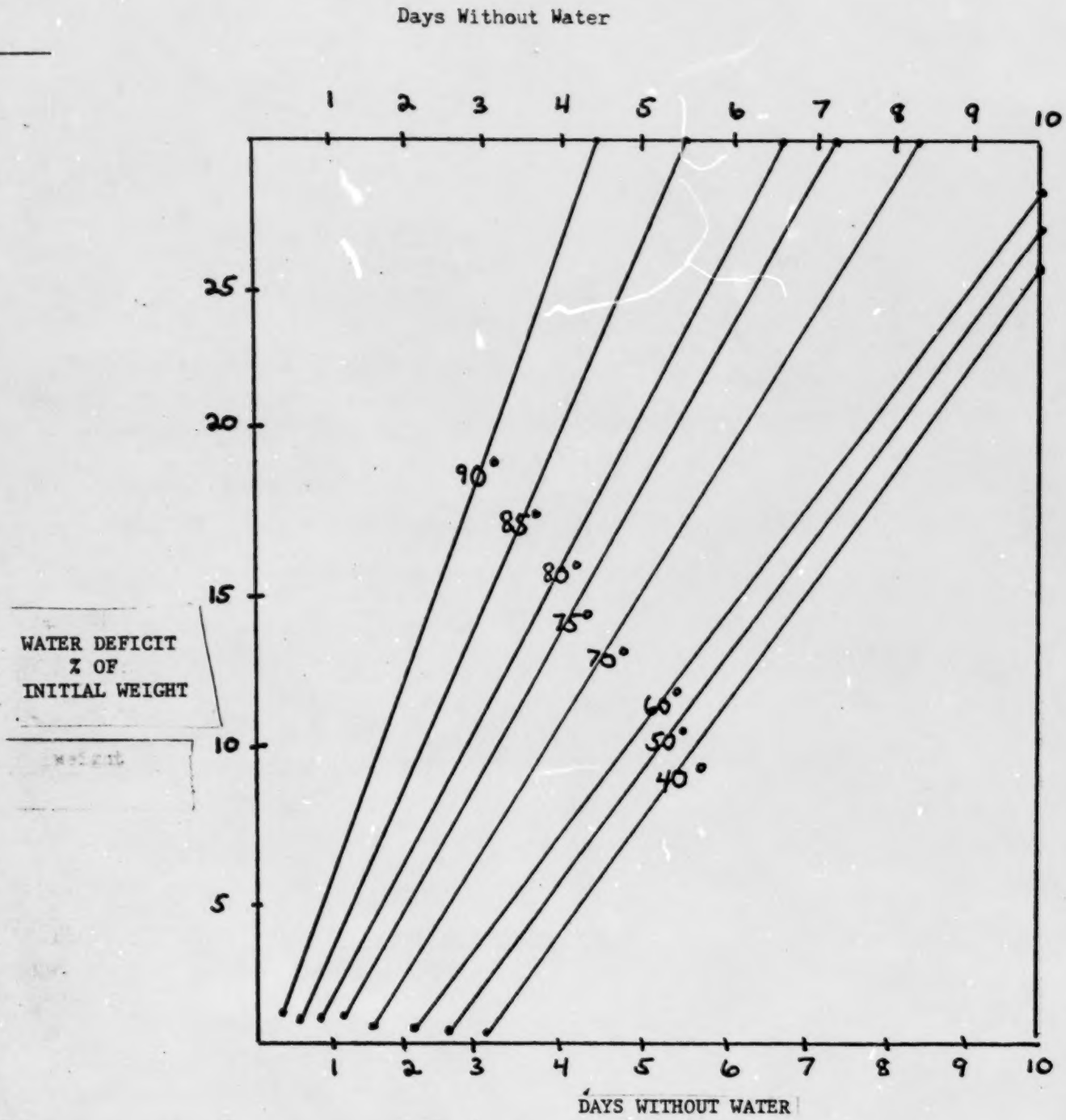
It should be noted that all of these amounts can vary greatly depending on the person, his diet, environment, and activity.[3]

If thirst is not always a good indicator of true body needs, what then are good indicators of water needs? Symptoms experienced by men with an increasing negative water balance are: 1. muscular fatigue (being the most common), 2. thirst (noticeable at first but not increasing with severity in many cases), 3. vague discomfort in the form of heat oppression, sleepiness, and dizziness, 4. urine discoloration (becoming darker and thicker), 5. nausea, and 6. headache. As dehydration becomes more acute, vision becomes dimmed, hearing is impaired, skin develops a sunken and somewhat rigid appearance. Along with this rigidity, numb and bloody cracks appear. These symptoms indicate that a point of no return is reached with the lethal point being between 15 and 25 per cent water deficit (loss of body fluid weight). At a deficit of 12 per cent the inability to swallow is reached and a man must be given water intravenously or if this is impossible, very small amounts of water must be given, slowly, to allow any possible absorption to take place. At a 2.5 per cent water deficit a man loses over 25 per cent of his efficiency, as he does if the temperature (ambient) approaches 110 degrees F. or over.[4] At this stage of water deficiency, group cooperation cannot be expected and gross mental deterioration becomes evident.[5] The effects of heat and time, as a function of water deficiency are illustrated in Charts 2 through 4 on the following pages.

Stages of Dehydration

With the physical symptoms, negative water balance proceeds in three successive stages. Stage one is called the stage of normal dryness. Thirst is apparent in this stage along with general uneasiness and irritation which accounts for the fact that this is also called, the clamorous

Chart 2



Body Weight versus Days without Water

Chart 3

EXPECTED DESERT SURVIVAL

Page 5

SURVIVOR NIGHT WALKING

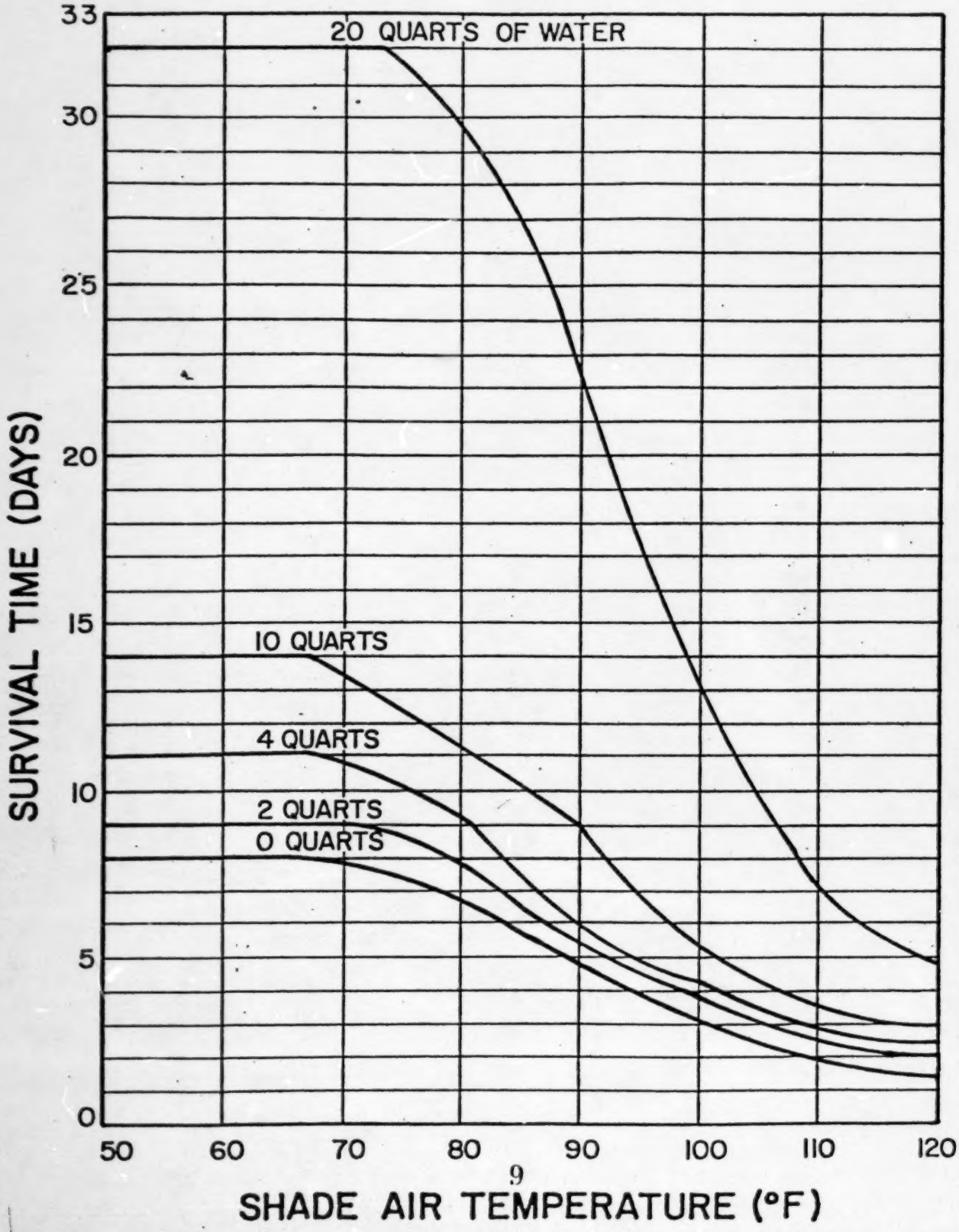
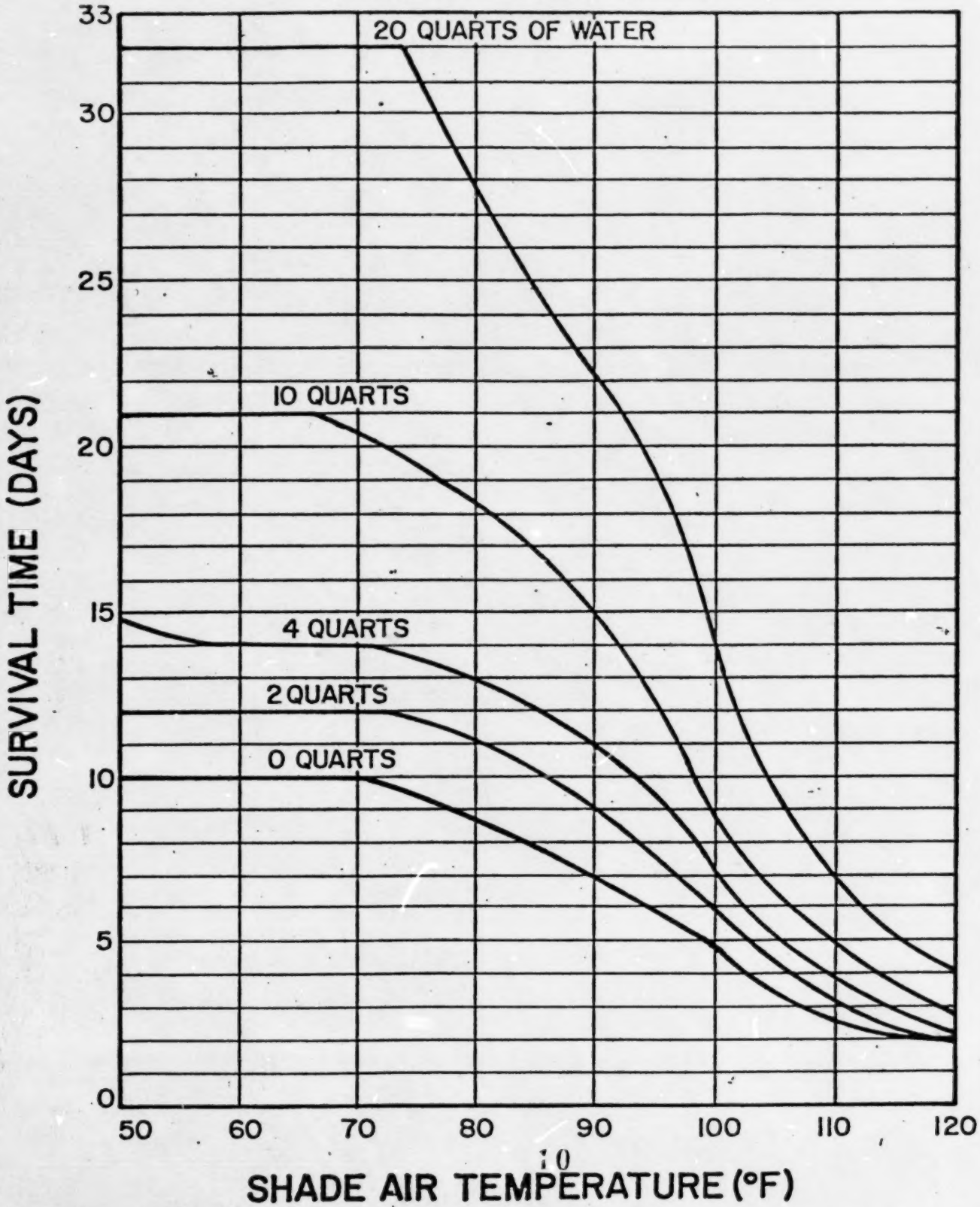


Figure 5

SURVIVOR STATIONARY



stage. While stage one has been experienced by many people, many times, and is not considered dangerous, it is significant in that it is the beginning of a water problem. Stage one can be thought of as a warning signal of impending trouble, if the person is aware enough to notice it.

Stage two is also known as the "cotton mouth" stage. Its characteristic symptoms are dry mouth, scant mucus or saliva secretion, skin shrinkage, cracked voice, personality changes, (i.e. prejudices are intensified, sudden revulsions appear, clothing is stripped, and other abnormal reactions). The mind becomes disorganized and speech rambles. Breathing difficulties and skin numbness are experienced in the latter degrees of this stage.

Stage two symptoms are alleviated only by one substance - water. Depending on the severity of water lack, the water needed is either in quarts or gallons. This water should be drunk until satiety and then some. The water can be gulped, contrary to popular belief. There is little if any evidence supporting the notion that drinking water in large quantities, with a negative water balance, is deleterious.[6] In fact, the best performance for working in the heat has been recorded to be intermittent hard work with an hour by hour replacement of water lost through sweat.[7] However, the water should not be ice cold, since this will close the sphincter muscles of the stomach, preventing water absorption.[8] The latter phases of stage two can be thought of as the beginning of the end.

Stage three, the stage of structural degeneration, is fatal if medical aid is not forthcoming. The speed at which a person goes from stage two to stage three is largely dependent on the victim's

physical condition, especially his inurement (tolerance) to hot climates. In this stage, the lips become cracked, blood flow through wounds becomes thick and viscious, the gums shrink and walking becomes uncoordinated and extremely difficult. The mind loses all or most of its ability to rationalize, sight and hearing dim until unconsciousness develops, followed by irrevocable death from hyperthermia. Damage occuring during the third stage is frequently irreversible even with medical help.

Responsibility of Outdoor Leaders

Outdoor Leaders face a major, two-fold task. First, recognizing negative water balance problems and second helping the victims combat them. The obvious question is: "How can I avoid dehydration or negative water balance?" The obvious answer is by water intake and water loss reduction. This sounds easy but often it is not.

Fresh water is the most readily assimilated form of water utilized by the body. Water that is contaminated by salt in concentrations greater than osmotic potential gradient tend to cause body cells to give up their water instead of absorbing it. Because of this reason salt water cannot be absorbed by the body either via the stomach, enema, or skin.

Salt water does have a dual purpose in the survival situation. The first of these being the fact that salt water can be used to cool or lower the outer skin temperature through evaporation. This can be accomplished by wetting the skin or clothing of the survivor. It also should be noted that when water losses are high, through respiration, a damp piece of cloth placed over the mouth and nose will reduce these losses considerably.[9]

The second use of salt water, although controversial in nature, will be dealt with as it may be a possible utilization technique. This technique is fresh water adulteration or the mixing of salt water with fresh water in an attempt to extend the total supply. While at first thought, fresh water adulteration would seem to be a survival error, this very principle is accomplished everytime the desalting kit is utilized. In fact, the desalting kit is designed to retain approximately ten percent of the original salt content. This ten percent is retained in an effort to obtain a more favorable water balance with the salt instead of pure fresh water. The remainder of the salt is precipitated out in the form of insoluble silver chloride, barium sulfate, magnesium hydroxide, and zeolites. These insoluble particles are then filtered out and activated charcoal added for taste and odor removal.[10]

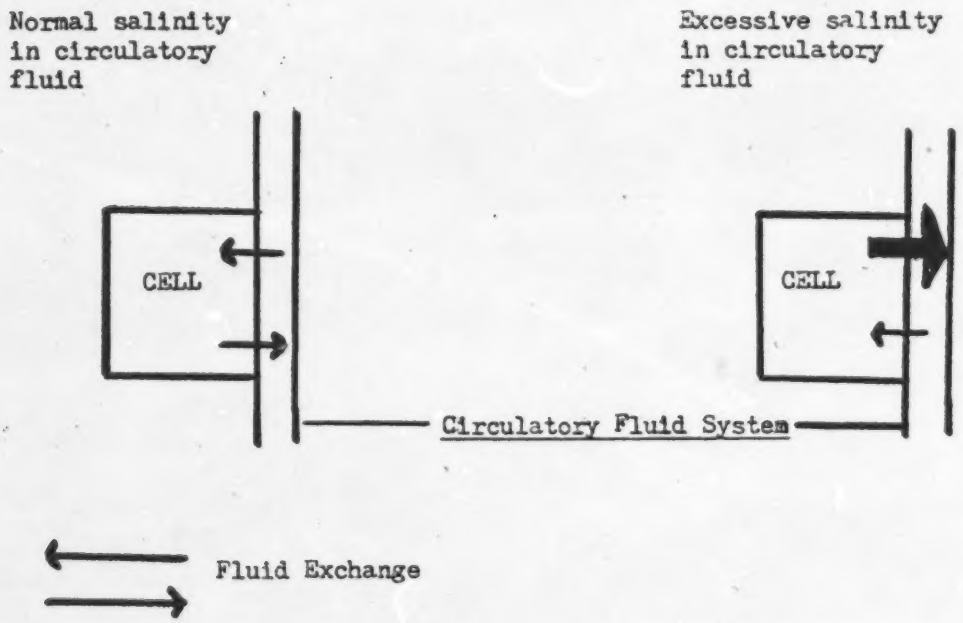
While there is some evidence that freshwater adulteration (with saltwater) will help maintain the circulatory function (Bubini, Wolf, Meroney, 1956, Gamble 1944, Elkinton and Danowski, 1955, Prentiss, and Douglas and Smith 1959), it should be noted that while the circulatory system is benefitted to some extent, this benefit is derived at the expense of cellular function.[11] Even considering this problem, "Many physiologists have nevertheless still not entirely discarded the idea that just a little seawater, 'limited' mariposia, may assist in survival and save some small fraction of body water.[12]

However, for every physiologist that thinks salt water - fresh water mixing may be of some value, there is another physiologist that

believes it to be a dangerous practice. With any sea survival situation there is usually a considerable amount of salt water ingestion. This ingestion of saltwater can significantly raise the salt level of the body, thereby adding to the problem of too much salt in the body. As a general survival rule, the Outdoor Leader should stay away from advocating any use of salt water, except for cooling purposes, until more definitive evidence is obtainable.

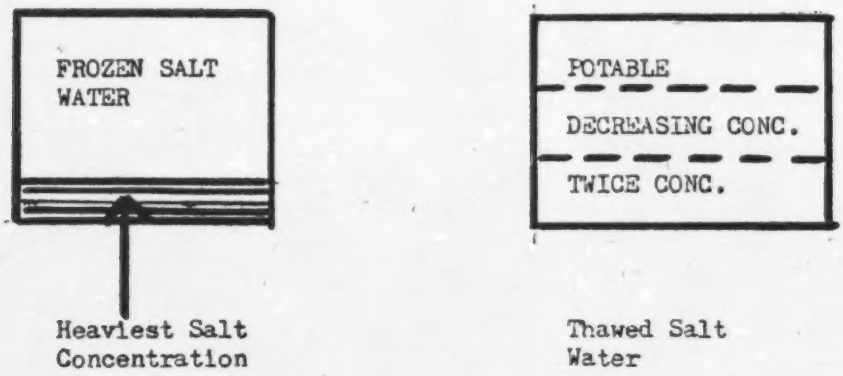
The following illustration depicts the process by which salt water causes an increase in circulatory fluid at the expense of cellular fluid.

Chart 5



Freshwater can be gleaned from frozen salt water, if care is taken during the thawing process. When salt water is frozen the salt tends to concentrate toward the bottom of the container. If the salt water is allowed to melt the fluid will tend to seperate into fractions. The concentration of salt contained in these layers will vary from over twice the original concentration in the lowest layer to less than one - tenth in the highest layer. The first thirty percent of the original amount of salt water is potable, assuming there has been no mixing.[13] The following diagram illustrates this point.

Chart 6



It is also a well known survival fact that old sea ice, (blue in color) is potable, while new sea ice, (white in color and very flexible) contains too much salt to be usable.[14] With aging, the brine mixture moves downward through the ice. As it moves downward through

the ice block the crystals of ice grow closer together, causing the salt particles to be "pushed out".[15] Salt water also thaws more readily than does fresh water and the salt is leached out with time.

The fluid from fish (commonly called stickwater) was often thought of as a water substitute. The fact is, a human being can not concentrate the urine sufficiently to allow utilization of this fluid without further dehydration. Fish fluid contains large amounts of proteins and oils. Consequently, what water is contained in the fluid is used in metabolism thereby increasing the body's need for water.[16]

Historically, urine has been mentioned as a water substitute. Once again, such is usually not the case, with urine adding nothing to the body's water balance. Because of the lack of osmotic space, i.e. the kidney's inability to concentrate urine beyond a certain point, urine actually causes the formation of more urine, which in turn further increases the body's need for water.[17] This does not appear to be the case if the urine is dilute, such as from a fully hydrated, non-sweating person. If hydrated, a person's urine during the first twelve hours may be beneficial to his water balance.[18] This is assuming that there is no great loss of water by sweating and that the survivor can cope with the psychological effect of drinking urine, (uriposia).

However, the use of urine has some survival value. Urine can be used to wash wounds, stings, and bites. It can also be used in the evaporation process to cool the skin temperature and in the operation of a solar still.[19]

While drinking blood has been used as a liquid or water substitute, it is not and should not be considered as such. Both the higher osmotic pressure and the presence of proteins and fats cause the body to "give up" more water, through metabolism, than is gained.[20]

The use of plants for water is a well established fact, and need not be discussed to great length in this paper. It will be noted, that some of the plants used for water or a water substitute are: grass, Aloe Berries, Barrel Cactus, Prickly Pear, Water Vines, Bamboo and Fig.[21]

The next obvious question is; how can I delay dehydration if faced with a water shortage. It is of paramount importance to apply appropriate survival principles. Some of which are as follows:
1. Drink when thirsty, within reason, or when water is needed.
2. Ration your sweat not your water, (water in small quantities does nothing to inhibit the onset of dehydration, while larger amounts will delay or alleviate these effects). 3. utilize all available shade - perform tasks which require the expenditure of energy in the cooler night temperatures. 4. Within reason store water in your stomach not your canteen, people have been found dead of dehydration with water in their canteens. 5. Keep your clothes loose fitting and layered to protect from the heat, sun and evaporation. 6. Keep conversation to a minimum to avoid water loss through the mouth. 7. Avoid all types of dehydrators, i.e. foods, alcohol, blood, and salt.[22]

Since the water content of urine varies particulary with the development of dehydration, attempt to concentrate urine. Conceivably,

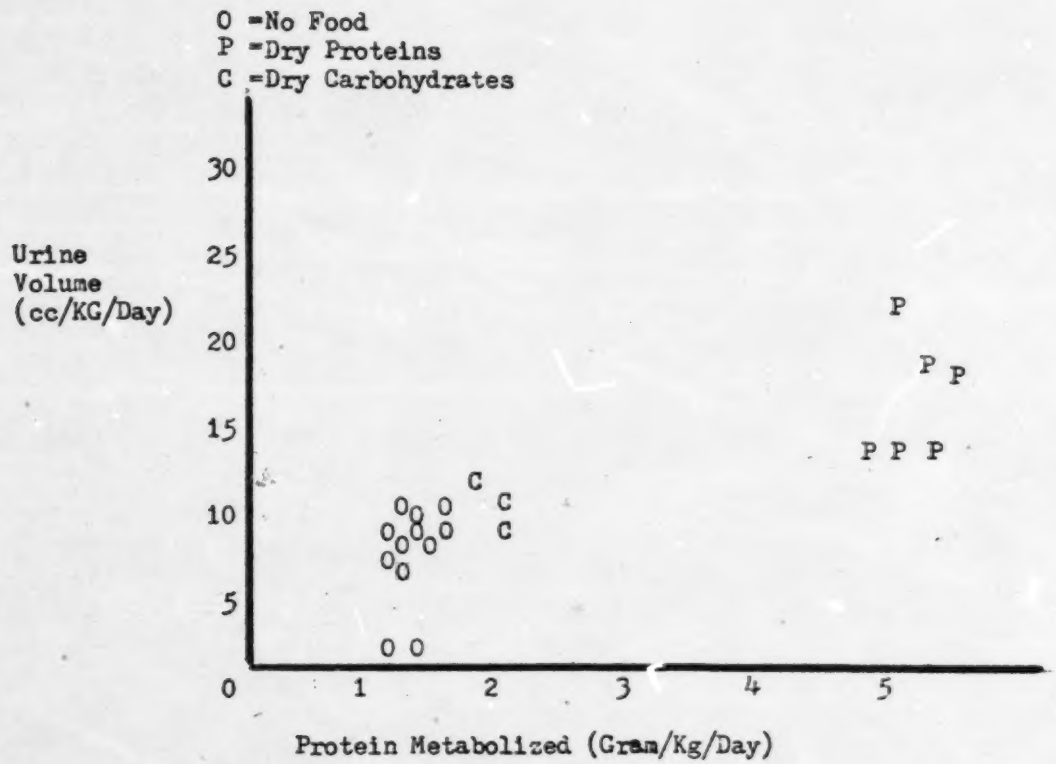
this will provide more water for life processes. When castaway with limited supplies of water, do not consume any, unless heavy sweating occurs, for a period of twenty four hours. In that time the body will tend to concentrate its urine toward the minimum amount for waste elimination. The remainder is available for other more immediate physiological processes. Water taken in before this time period, usually goes into the formation of less concentrated urine, and is "wasted" for the survivor's purposes.[23]

Food has already been mentioned as a dehydrator, although certain foods are less so than others. Primarily, of the three classes of foods (carbohydrates, proteins and fats), the carbohydrates require the least amount of water to oxidize. In fact, the sugar glucose displaces 0.648 cc of water per gram and yields 0.600 cc of oxidative water. The addition of sugar to the diet also helps prevent ketosis, (incomplete oxidation of fats) and "sour stomach".[24] How this sugar is stored or in what type of food is of course up to the individual, however, when in the form of candy, the hard candies have been known to produce mouth sores while the soft jelly types produce no such problem.[25]

Fats and proteins require a greater amount of water to metabolize, primarily because of the greater and more complex bonding of the individual molecules. Since complete metabolism of fats is difficult, the residue must be removed or "washed out" of the system or it will become acidotic. This metabolic acidosis requires additional supplies of water. With proteins, the large amounts of nitrogen present causes additional urea formation and consequently requires additional water for elimination.

The following illustration depicts the various effects of proteins, carbohydrates, and lack of food on the urine volume (water loss - greater the urine volume - the greater the dehydration effect on dogs).

Chart 7



Cold Diuresis

Outdoor Leaders observe in both themselves and their students an increase in urine output in colder weather. This can be noticed even with a decrease of water input. This occurs as a result of the body eliminating the excess fluid volume resulting from constriction of

The peripheral vasculature. Maximum vasoconstriction occurs in the second hour of exposure.[26]

Conclusion

Because of the length and complexity of the dehydration problem, a summary is in order, concerning the basic points presented in this report:

1. The human body consists of over seventy per cent water.
2. Water is used by the body in food metabolism, muscle tonicity, waste elimination, temperature regulation, and cellular upkeep.
3. Water loss occurs through respiration (especially at high altitude), evaporation, waste elimination, and tissue destruction.
4. Water gain is accomplished through water intake and food oxidation.
5. There are two types of thirst:
   a. Local (called false thirst). False thirst is centered around the throat and esophagus.
   b. General (called true thirst). True thirst is concerned with the total body requirements.
6. Common antidipticums (materials that lessen thirst symptoms) are: small pebbles, cocaine, buttons twigs, licorice, gum and saliva.
7. Thirst is not always a good indicator of body water needs.
8. Dehydration symptoms:

1-5% of body weight	6-10% of body weight	11-20% of weight
economy of movement	dizziness	delirium
thirst	headache	swollen tongue
vague discomfort	tingling in limbs	inability to swallow
flushed skin	reduced salivation	deafness
sleepiness	indistinct speech	dim vision
increased temperature	difficulty in walking	numb skin
increased pulse rate		painful urination
nausea		

9. Negative water balance proceeds in three successive phases:
   a. Stage of normal dryness
   b. Cotton mouth stage
   c. Structural degeneration

10. Salt water has a dual survival purpose:
    a. Cooling of body through evaporation
    b. Possible use of salt water and fresh water mixing - however this is still a very controversial subject and should be regarded with great caution.

11. Thawed sea water settles into layers of increasing salt concentration while with frozen sea water, the highest salt concentration is at the bottom of the container.

12. Fish fluid (stickwater) is not a water substitute because of two primary reasons:
    a. The proteins and oils contained in the fluid demand more water to metabolize than they contain or produce, thus making it more of a food source than a water substitute.
    b. Stickwater is extremely difficult to procure in most situations.

13. Urine may or may not be used as a partial water substitute, depending on the factors of hydration and sweating. It can be used in cooling the body, through evaporation, and in solar still operation.

14. Blood is not a water substitute because of the large amount of water needed to digest it.

15. Many plants provide acceptable water sources, and should not be overlooked, in a survival situation.

16. Negative water balance problems can be delayed or prevented by:
    a. Rationing your sweat-not your water.
    b. Reduce temperature gain-mainly through the use of shade & night versus day activity.
        1. Your body loses 25 % of its efficiency with an air temperature of 110 degrees or above.
        2. Your body will lose 25 % of its efficiency with a loss of 2.5 % of its body fluids.
    c. Store water in your stomach-not your canteen, within reason.
    d. Keep your clothes loose and layered.
    e. Avoid dehydrators, such as foods, excessive alcohol, and salts.
    f. Avoid water intake (unless with extreme sweating), for the first twenty four hours, to concentrate the urine.

17. Of the three foods: carbohydrates, proteins and fats, the carbohydrates require the least amount of water because of the chemical bonding.. Proteins require the most water to metabolize and excrete, because of the nitrogen containing compounds formed, such as urea.

18. Cold diuresis causes an increase in urine output in cold environments.

ENDNOTES

[1]A.V. Wolf, PhD., Thirst-Physiology of the Urge to Drink and Problems of Water Lack, (Charles C. Thomas, Publisher, 1958), p. 50.

[2]Ibid., p. 50.

[3]Helen Andrews Guthrie, Introductory Nutrition, (C.V. Mosby Company, 1971), p. 180.

[4]Department of the Air Force, Air Force Manual 64-3, 1969 p. 4-9.

[5]A.V. Wolf, PhD., Thirst-Physiology of the Urge to Drink and Problems of Water Lack, (Charles C. Thomas, Publisher, 1958),p. 219.

[6]Ibid., pp. 145-146

[7]Ibid., p. 224

[8]Ibid., p. 146.

[9]Ibid., p. 268.

[10]Ibid., pp. 242-243.

[11]Dr. O.G. Edholm and A.L. Bacharach, eds. The Physiology of Human Survival, (Academic Press, London, 1965) pp. 268-269.

[12]Ibid., p. 268

[13]A.V. Wolf, PhD., Thirst-Physiology of the Urge to Drink and Problems of Water Lack, (Charles C. Thomas, Publisher, 1958),p. 237.

[14]Ibid., p. 237.

[15]Ibid., p. 237.

[16]Ibid., pp. 330-332.

[17]Ibid., p. 310.

[18]Dr. O.G. Edholm and A.L. Bacharach, eds. The Physiology of Human Survival, (Academic Press, London, 1965) p. 288.

[19]A.V. Wolf, PhD., Thirst-Physiology of the Urge to Drink and Problems of Water Lack, (Charles C. Thomas, Publisher, 1958), p. 311.

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[21]Department of the Air Force, Air Force Manual 64-3, 1969.

[22]Sun, Sound, and Survival, EID Publication, No. D-102.

[23]A.V. Wolf, PhD., Thirst-Physiology of the Urge to Drink and Problems of Water Lack, (Charles C. Thomas, Publisher, 1958), p. 15.

[24]Ibid., p. 280.

[25]Ibid., p. 290.

[26]Ibid., p. 196.

Glossary

Adipsa: Remedies to allay thirst.

Antidipticum: An agent that lessens thirst.

Balance: Equality of intake versus output.

Dehydration: Water deficit; negative water load.

Dipsogen: A thirst provoking agent.

Euhydration: Normal state of body water.

Insensible Perspiration: Water loss through the skin, in amounts usually too small to be readily detected.

Obligatory Urine Flow: The minimal volume of urine consistent with the excretion of its solute.

Osmotic Pressure: The pressure of a solution which governs the tendency of its solvent to pass across a boundary.

Potable: Drinkable water.

Uriposia: Urine drinking.

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